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Abstract

Although tomato flavour has not been a major goal for breeders, nowadays it becomes important as it is a subject of consumer complaint. A better knowledge of tomato consumer preferences, at the European level, should provide the basis for improvement of fruit quality and for market segmentation. In the framework of a large European project, 806 consumers from three countries, The Netherlands, France and Italy, were presented with a set of 16 varieties representing the diversity of fresh tomato offer in order to evaluate their preferences. In parallel, sensory profiles were constructed by expert panels in each country. Preference maps were then constructed in each country revealing the structure of consumer preferences and allowing identification of the most important characteristics. Then a global analysis revealed that preferences were quite homogeneous across countries.

This study identified the overall flavour and firmness as the most important traits for improving tomato fruit quality. It showed that consumer preferences from different European countries, with different cultures and food practices, are segmented following similar patterns when projected onto a common referential plan. Moreover the results clearly showed that diversification of taste and texture is required to satisfy all consumers' expectations as some consumers preferred firm tomatoes, while other preferred melting ones and were more or less demanding in terms of sweetness and flavour intensity. Detailed comparisons also showed the importance of the fruit appearance in consumer preference.

Key words : consumer acceptance, descriptive analysis, external preference, sensory analysis, internal preference Mapping; tomato

Practical application

The consumer preferences for fresh market tomato were studied in three European countries. The main descriptors for further breeding for consumer satisfaction were identified. Four clusters of consumers were identified in the overall analysis, the three countries contributing the same way to each cluster. The impact of appearance in the preferences was also underlined.

Introduction

Tomato is the primary vegetable produced and consumed in the world after potato. In Europe, consumption varies greatly between countries with a clear gradient from the south to the north, with for instance 42 and 15 kg/capita/year consumed in Italy and the Netherlands, respectively (http://faostat.fao.org/). Since the 1990's and concomitantly with, on the one hand the availability of tomato all year long and on the other hand a move towards much firmer fruit, consumers tend to complain about tomato taste (Hobson 1988; Bruhn and others 1991), often blaming modern cultivars for lack of flavour. Until recently, quality was not the main objective for tomato breeders who first improved yield, adaptation to specific growth conditions, disease resistances and fruit shelf life. As sensory quality has become an important objective, breeders need clear targets and tools to improve fruit quality. Tomato fruit quality for fresh consumption is determined by a set of attributes, describing external (size, colour, firmness) and internal (flavour, aroma, texture) properties. Sensory analysis is an efficient way of describing these internal properties and to analyse consumer preferences. Relationships between tomato taste and fruit characteristics have been widely studied. Flavour is mostly due to the content in sugars and acids (Stevens and others 1977), to their ratio (Stevens and others 1979; Bucheli and others 1999), and to volatile aromas. More than 400 volatiles have been identified (reviewed by Petro-Turza 1987), about 30 of them contributing to the particular aroma of tomato fruit. Sweetness and sourness are related to sugar and acid content (Stevens and others 1977; Janse and Schols 1995; Malundo and others 1995). Both sugars and acids contribute to the sweetness and to the overall aroma intensity (Baldwin and others 1998). Texture traits are more difficult to relate to instrumental measurements, although firmness perceived when eating is partly related to compression tests (Causse and others 2002), and mealiness can be related to the texture parameters of the pericarp (Verkeke and others 1998; Devaux and others 2005; Chaib and others 2007).

Genetic variability for quality traits has been reviewed by Davies and Hobson (1981) and Stevens (1986), whilst Dorais and others (2001) reviewed the impact of environmental conditions in greenhouse production. Genetic variation has been identified for every quality

components (Davies and Hobson 1981; Langlois and others 1996; Causse and others 2003; Tikunov and others 2005). Most of the studies on genetic variation in fresh tomato quality describe a few cultivars or compare groups of cultivars (cherry, cocktail, beef types), and preferences of consumers faced with genetic variability have rarely been studied. Cherry tomatoes, with fruits rich in acids and sugars, are usually preferred (Hobson and Bedford 1989). In contrast, long shelf life cultivars have been described as less tasty than traditional ones (Jones 1986), with lower volatile content (Baldwin and others 1991). Analysis of trait inheritance shows a polygenic control of most of the traits (Stevens 1986; Causse and others 2003).

Several studies have been set up to identify the most important characteristics for consumer preferences. Acceptable tomato fruit must be high in tomato-like aroma intensity and in sweetness, but intermediate in acidity (Jones 1986; Baldwin and others 1998, Alonso and others, 2010). Malundo and others (1995) show that given levels of sweetness correspond to optimal acid concentrations, beyond which acceptability decreases. Baldwin and others (1998) relate the overall acceptability to the ratio of sugars to titratable acidity, and to the concentration of several aroma compounds. Verkeke and others (1998) underline the role of texture traits in the preference of consumers. Causse and others (2003) show that consumer preference for fruit firmness reaches an optimum that can be obtained in hybrids between firm modern and traditional soft varieties. By comparing consumer preferences, sensory profiles and physico-chemical attributes, several groups of consumers differing in their liking of tomato varieties have been identified, mainly differentiated by sweetness and tomato flavour on the one hand and firmness on the other hand (Lê and Ledauphin 2006; Lengard and Kermit 2006).

The present experiment aimed at comparing the consumer preferences across three European countries. More than 800 consumers from the Netherlands, France and Italy were presented with a set of 16 varieties representing the diversity of tomato available in the market in order to evaluate their preferences. In parallel, sensory profiles were established by trained sensory panels in each country. Preference maps were constructed and cluster

analysis revealed the structure of consumer preferences in each country and allowed identification of the major traits to improve in order to satisfy the diversity of consumer tastes. The results obtained in one country, Italy, are presented in detail in Sinesio and others (2010). We thus herein present briefly the results obtained in France and the Netherlands and then the global analysis of the data obtained in the three countries. Comparison of sensory profiling strategies is also performed.

Materials and Methods

Plant Materials

Nineteen cultivars were grown but only 16 were tested in each country (Table 1), 13 were tested in the three countries, 3 were tested in two countries, and 3 were tested in only one country. Eight cultivars were grown in the Netherlands and 11 in France (5 in grower's greenhouse from the West and 6 from growers in the South East). Fruits were harvested in each location over 3 consecutive weeks in June 2007 and were sent successively to the Netherlands, to Italy and to France. The tomatoes were selected primarily from the harvest site before being transported to the test locations. The harvests took place on Wednesday and Thursday of the previous week at a level of maturity of 7-8 on a 11-point color scale and travelled for a maximum of 5 to 7 days. The level when tasting was 10-11. The fruit selection ensured the minimum variation within a cultivar in colour, size and firmness.

The latter is regarded as the most important criterion. An ideal firmness was determined by a gentle finger pressure which should give only a slight indentation on the locular cavity wall, but be firm between the cavity walls. Although the primary selection was done, the sample quality was also checked at each test locations. Tomatoes which greatly differed from the other fruits of a cultivar in size or colour, or physically damaged/ bruised during the transportation were removed.

A sufficiently large number of fruits was sent to select batches of fruits homogenous for size and color within each cultivar. After harvest, fruits were stored at 12°C, and were taken out to acclimatise to room temperature a day prior to the evaluation.

Sensory evaluations

To evaluate the sensory characteristics of the tomatoes, the sensory panels were trained by an adapted Quantitative Descriptive Analysis (QDA®) methodology during 4 (in Italy) to 6 (in France and Netherlands) training sessions. Performances of the panel have been controlled during the last training session, where the consensus, accuracy and repeatability of the results were validated as described in Sinesio and others (2007) and Lê and Ledauphin (2006). Trained sensory panels were composed of 15 assessors in France, 8 in Italy and 10 in the Netherlands. These panels were already specifically trained for the evaluation of tomatoes. Tasting sessions took place in sensory analysis laboratories (AFNOR XP V09-105), in white light, at a temperature of 22°C ± 2°C. The samples were removed of the stalk and crown, washed with cold running water dried with a paper towel. A whole tomato was presented per sample in a plastic plate. The samples were presented as a blind man (identified by codes with 3 random numbers), in a monadic mode, and in a complete balanced experimental plan. The presentation orders were optimised in order to limit the order effect.

As panellists in each country had previously generated a list of descriptive terms for tomato texture and flavour and had consensus definitions for each attribute (Lê and Ledauphin 2006; Sinesio and others 2007), a set of 8 descriptors common to the three countries was used but specific descriptors familiar to the assessors were added in each country (**Table 2**).

Each panel was free to adopt its own glossary and evaluation scale to avoid changing their habits. They all attended several pre-testing sessions during which they familiarised with the test samples and experienced the range of variation of each sensory descriptor. Descriptors were selected for being perceived as appropriate to the product and quantitatively different in the sample set. In France the panel tasted 16 cultivars in 2 days (8 products tasted per day

in 2 sessions separated by a 15' break) and gave a score from 0 to 10. Each product was thus tasted once by each panellist. In Italy and the Netherlands, the 16 cultivars were tasted twice by each panellist and scores were noted on a scale from 0 ("nul") to 9 ("strong").

Consumer tests

Consumer tests were performed in 2 or 3 locations per country, in Avignon, Paris and Rennes in France (304 consumers), in Milan and Naples in Italy (179 consumers) and in Delft, Heerlen and Utrecht in the Netherlands (323 consumers), for a total of 806 consumers. The consumers met the following criteria: They had to be regular consumers of (fresh) salad tomatoes (with a minimum frequency of one consumption event per month), over 18 years old and have not taken part in a market research survey on tomato during the three months before the test. The panels were equilibrated in gender and age although the frequencies of age segments per location could differ. Central location test were conducted for each panel. No information was provided to the consumers about the tomato cultivars.

The French panel was composed of 100 people per site, recruited by the service provider, (Sensory Evaluation Laboratory of PEIFL, Avignon). The panels were managed according to standard XP V 09-500 "Sensory Analysis - Methodology - general Directives for the realization of hedonic tests in sensory evaluation laboratory in controlled conditions implying of the consumers". In France the tests were performed during 2 successive sessions, each consumer assessing 8 fruits per session, following a sequential monadic mode, in sensory analysis boxes, under white light. The tomatoes were presented entire, placed on their peduncular face in plastic plate. The consumers had a kitchen knife and an explanatory card about the tasting protocol. They had water in bottle (Evian) to rinse their mouth between two samples. The products were presented according to a complete balanced experimental plan. No dummy sample was presented. Each sample was presented "as a blind man", i.e. identified by a random code with 3 digits. The hedonic tests were carried out in parallel in the 3 locations (Avignon, Paris, and Rennes). Consumers gave a score from 1 (do not like) to 9 (like very much) for the overall appreciation. To describe the segments of consumers

according to their attitudinal and usage characteristics, at the end of the last test session, after answering the hedonic questionnaire, the consumers were asked to fill a questionnaire in which information on consumption habits and demographic information were requested.

In Italy 3 sessions were performed over 3 days as described in Sinesio and others (2009). Consumers tasted 5 or 6 tomatoes in each session. The scale was the same as in France. Appearance was also scored independently. In the Netherlands 8 fruits were scored in 2 sessions, over 2 consecutive days. Consumers started with the tasting of a dummy sample that was not included in the data-analyses, followed by eight tomato samples according to a balanced block design. The session duration was about 1 hour. Crackers and water were supplied to clean the palate between tastings. The tests started with the evaluation of appearance, familiarity and taste, in that order. Consumers were asked to indicate on a 9-point scale anchored by “dislike extremely” (1) to “like extremely” (9). The samples were served in separate transparent plastic containers: one container with an integral, unwashed, fruit for appearance and familiarity, and a second container with a defined part of tomato for the taste evaluation. Consumers were allowed to swallow the tomato segment.

Samples were served within 15 minutes after cutting. To describe the segments of consumers according to their attitudinal and usage characteristics, at the end of the last test session, after answering the hedonic questionnaire, the consumers were asked to fill a questionnaire in which information on consumption habits and demographic information were requested.

Statistical analyses

All the analyses were performed using the Rgui software (R Development Core Team 2008) and the SensoMineR package devoted to sensory analysis (Lê and Husson 2008).

Country per country analysis

For each country, an ANOVA was first performed on the sensory data with the model:

Descriptor = Mean + Product + Judge + Product x Judge + error,

except in France where the interaction could not be tested. Function *decat* of SensoMineR was then used to estimate the average of each product for each descriptor. Then a Principal Component Analysis (PCA) was performed to summarise visually the data. On consumer data, an ANOVA was also performed on the following model: *Hedonic score* = *Mean* + *Product* + *Consumer* + *error.*

Then external preference mapping was performed on the average value adjusted per product and descriptor and the scores given by each consumer to each product; a PCA was performed with the descriptors as active variables (function *carto* of SensoMineR). The consumer preferences were then segmented by cluster analysis on the liking scores centred on the average of each consumer. A Ward's hierarchical cluster analysis was used with Euclidian distances and the number of clusters validated by k-means. Each cluster was then described according to the consumer's answers to the questionnaires and to the cultivars that were significantly characteristic for each segment.

A multiple factor analysis (MFA) was then performed on the table that described the tomatoes, one line per cultivar, with as many columns as sensory attributes and consumers. The three groups of descriptors from each country constituted the active groups, balanced in order to give the same weight to each group. Three groups composed of the preference scores of each country were then projected on the common plan, which allowed the comparison of preference maps. Products that were specific to one or two countries were added as supplementary individuals (BS1504, Cotabel, Marmandino, Picolino, Savantas and Thesis). A hierarchical MFA was finally performed integrating all data (function HMFA in SensoMineR). The fact that the groups of descriptors are different from one country to another is taken into account in the Multiple Factor Analysis (MFA) and in the Hierarchical Multiple Factor Analysis (HMFA). These methods were developed to take into account such structure of variables organised in several groups (variables are descriptors and groups, the three countries). In the HMFA, in each country, two groups of variables were considered, hedonic scores and sensory descriptors. The MFA (Pages and Tenenhaus, 2001) works as a weighted PCA. According to this method each variable belonging to group j is weighted by

249 $1/\lambda_1^j$, where λ_1^jdenotes the first eigenvalue of the matrix of variance–covariance associated
250 with each data table Xj. (for more details see Pages & Tenenhaus, 2001). This kind of
251 standardization on a data matrix is analogous to the one used on variables when doing a
252 PCA on the correlation matrix. The MFA weights the contribution of each group (country) and
253 permits a common referential to be obtained, including all the sensory descriptors. We thus
254 construct a preference map of all the products for each country on the same reference of
255 sensory descriptors.
256
257
258 **Results and Discussion**
259
260 ***Descriptive profiles and consumer preferences in France***
261 In France, 16 cultivars were described by 15 panellists with 15 descriptors for appearance,
262 flavour, texture, odour and taste (**Table 2**). The cultivar and judge effects were significant for
263 all the descriptors except salty taste and odour intensity (data not shown). **Table 3** shows the
264 range of the mean score per cultivar and descriptor. The projection of the descriptors on the
265 first plan of the PCA based on sensory profiles explained 66% of the variation (**Fig. 1**). The
266 first axis was characterised by appearance descriptors (colour, size, ribbed) but also by
267 sweet and acid tastes, odour and flavour intensity opposed to mealy texture. The second
268 axis opposed melting and juicy to firm, crunchy tomatoes. The 304 French consumers scored
269 each fruit from 1 (“I do not like”) to 9 (“I like very much”). The average scores per cultivar
270 ranged from 4.63 to 7.19. The product effect was significant in the ANOVA and eight cultivars
271 appeared significantly different from the average, Picolino, Red Delight and Savantas being
272 scored higher than average and Fergie, Maribel, Climberley, Nun3120 and Cotabel lower
273 (**Table 4**).
274 **Fig. 2** shows the projection of the hedonic scores on the first plan of the PCA constructed
275 with the sensory traits. This external preference map confirmed that Picolino and Red Delight

were preferred as 80% of the consumers scored them higher than the average. On the contrary, Alison, Nun3120 and Bonaparte were the least appreciated. The classification of the consumer scores by cluster analysis clearly suggested four clusters (data not shown). The cultivars that were different from the average in each segment are presented in **Table 4**. Picolino was significantly preferred in each segment. According to the questionnaires, the segment 1 was characterised by a large number of old people (39% were more than 65 years old). They liked several types of cultivars, but the differences between the average scores per cultivar were not strong. It was difficult to characterise their preferences according to the sensory traits. Consumers of this segment frequently buy their tomatoes in open market. Segment 2 was the largest group with 98 consumers. The consumers of this segment did not like ancient type cultivars (like Marbonne and Cotabel with large ribbed and melting fruits), but preferred Exquise a cultivar with large round fruits. Segment 3 consumers (49 consumers) particularly liked Picolino and Red Delight, with small and juicy fruits with intense flavour. They favoured taste and flavour, and did not like the mealiest cultivars Fergie and Cotabel. On the contrary to segment 2, the 85 consumers belonging to segment 4 appreciated ancient cultivars with soft melting fruits like Marbonne and Cotabel. They argued that they prefer sweet fruits and that thick skin is not a problem for them. Gender was not a discriminating characteristic.

Descriptive profiling and consumer preferences in the Netherlands

In the Netherlands 16 cultivars were compared (**Table 1**). The panel characterised the products with 27 descriptors including several after-taste descriptors (**Table 2**). Salty taste, several after taste (at_rough, at_chemical,…) and odour descriptors did not discriminate the products and were thus not considered in the subsequent analysis. **Fig. 3** shows the projection of the cultivars tasted in the Netherlands on the first plan of the PCA constructed on sensory profiles. The first plan explained 62% of the variation. The first axis opposed sweet, juicy tomatoes with a strong taste intensity to green-taste, sour, astringent tomatoes. The second axis was characterised by taste and odour intensity and spicy odour in the

positive part and by firmness in the negative part. Several cultivars were similarly appreciated, but Cheers and Red Delight were separated from the others by their sweet and green taste and by juicy texture, while Climberley and Plaisance were particularly firm, Thesis rather acid, with green taste and low sweetness.

The Dutch consumer panel was composed of 323 consumers spread in three cities. **Table 4** shows the average score per cultivar and those that were significantly scored higher or lower than the average score. The external preference map confirmed the preference for Red Delight and Cheers as more than 60% of consumers scored these lines higher than average (**Fig. 3)**. Cultivars Alison, Hipop, Bonaparte, Maribel and Nun3120 were less appreciated. The cluster analysis of preferences revealed four segments (**Table 4**). Consumers in segment 1 preferred sweet, juicy cultivars, with tomato-like and spicy taste. In this segment, 45% of the consumers had a higher school level. Flavour was more important to them than fruit size. Consumers in segment 2 attributed more importance to price than to fruit size. They buy their tomatoes in market place and frequently buy beef type tomatoes. They preferred Red Delight, Cheers, Plaisance, Maribel, Globo and poorly appreciated Marbonne and Nun3120. This segment seemed to appreciate many cultivars and their preference was not driven by a specific descriptor. Consumers in segment 3 look for fruit size and firmness. In this segment, 41% of the consumers had a medium school level and only 9% a higher level. They particularly liked Red Delight, Cheers, BS1504 and Climberley, but disliked Marbonne and Marmandino. Consumers in segment 4 said they look at the price and origin of tomatoes. On the contrary to the other segments, they did not particularly appreciate fruits of Red Delight and Cheers, but preferred tomatoes with a sour, astringent taste.

Preferences of Italian consumers are described in Sinesio and others (2009).

Overall analysis

Are the trained panels homogenous?

In order to have a description of all the tomatoes tested by consumers, we performed sensory descriptive profiling in each country. As sensory panels were already trained with

their own descriptive list of tomato attributes, we decided not to use a unique list but to have a minimum list of common descriptors (the 8 most important ones) and leave each panel with its specificity. The analyses per country provided much information and allowed the study of consumer clustering, but not a global analysis across countries. Several alternative methodologies were possible to compare the preferences in the three countries, using for instance only one set of descriptive profiles. Nevertheless in order to take into account all the information, we chose to perform Multiple Factor Analysis (MFA). The MFA weighted the contribution of each country and permitted a common referential to be obtained, including all the sensory descriptors. **Fig. 4** shows the first plan of the MFA comparing the results of the three panels for the eight common descriptors used in the three countries. Many descriptors, like firmness, tough skin and juiciness, were similarly perceived by the three panels, as their coordinates were very close from each other on the plan. Differences among countries were detected for sourness, saltiness and sweetness.

Consumer preferences across three countries

In order to compare the preferences across countries on a common plan, we performed a MFA taking into account all the descriptors. The three groups of descriptors from each country constituted the active groups, which were balanced in order to give the same weight to each group. Three groups composed of the preference scores from each country were then projected on the common plan, allowing the comparison of the preference maps.

The first axis (**Fig. 5**) opposed fruits with an intense flavour, sweet taste, juicy and melting texture (like Red Delight and Marbonne) to the crunchy, firm fruits with a green flavour or bitter taste (like Nun3120, Bonaparte and Alison). The second axis corresponded in the positive part to fruits with an acid taste and thick skin (like Picolino, Exquise, Globo).

The coordinates of a group of descriptors on the axis could be considered as a quantification of the link between this group and the corresponding factor. The three groups of descriptors were strongly represented on the first two axes (correlations ranging from 0.89 to 0.98), thus the first plans of the PCA performed on the data of each country were very close to the first

plan of the global MFA. The MFA allowed the projection of consumer preferences onto a common referential. **Fig. 6** shows the three external preference maps on this common plan. The preferences were very close in the three countries. Red Delight was preferred in the three countries, while Nun3120 had the lowest score. There were small differences for intermediate ranking cultivars, as for example Marbonne was appreciated in France, but less in the Netherlands, and Climberley was preferred by Dutch more than by French or Italian consumers.

Finally, in order to obtain complementary information on the characterisation of products and consumer preferences a Hierarchical MFA (HMFA) was performed. Two levels of comparison were taken into account. The first level consisted in comparing hedonic judgement to sensory description. The second level allowed comparison across countries. Firstly, two MFA were performed, one on the three groups of sensory descriptors, the other on the three groups of consumer scores. The coordinates of the products on the factor axes of each MFA were then used as data for the second MFA in which the two groups (sensory descriptors and preference scores) were simultaneously considered. We thus obtained the coordinates on the axes of the HMFA with two levels. The projection on the first plan of all traits is shown in **Fig. 7**. Most of the traits were correlated with the first axis, which opposed tomatoes with intense taste and flavour (sweet, acid, salty taste, tomato flavour) and a juicy texture to fruits with a bitter green taste and uncommon aftertastes or odours. The second axis was characterised by appearance descriptors (size, ribbed, pulp thickness, skin thickness). The first diagonal was related to texture opposing melting to firm fruits.

On the HMFA, tomatoes were separated on the same plans by trained panellists and consumers. The axes were common and the projections of the two clouds of sensory profiles and consumer scores were almost homothetic to the overall cloud. This means that cultivars were separated in the same manner by expert panels (with many descriptors) and consumers' unique scores. Nevertheless, the order of importance of the axes was different, as the first dimension of variability for trained panels was taste and flavour followed by appearance, while for consumers texture was the most discriminating. The second

388 dimension for consumers was correlated to the preference, revealing the existence of
389 cultivars appreciated by all the consumers (Red Delight) and others disliked by most
390 consumers (Cotabel). For some cultivars, like Marbonne, Red Delight or Cotabel, differences
391 were more striking (**Fig. 8**). These cultivars had visual characteristics (Red Delight a small
392 size, Cotabel and Marbonne ribbed fruits). They were also considered as specific by
393 consumers. This indicates that consumers took into account in their appreciation not only
394 fruit taste but also appearance. Appearance was only described by the French descriptors
395 (colour, size, ribbed) and for the cultivars discriminated by their appearance, French
396 descriptors were closer to consumer appreciations.
397
398 ***Discussion***
399 The objective of the experiment was to compare the consumer preferences for tomato
400 cultivars in three European countries. Today, the tomato market proposes to customers a
401 large range of segments including truss, cocktail, long, cherry tomatoes or “ancient” cultivars,
402 in addition to the common round fruits. The 19 cultivars assessed in this study covered a
403 large range of variation representative of the fresh market. Some of the cultivars showed
404 differences in appearance (fruit size, shape or firmness) and were clearly discriminated.
405 Other cultivars with less visible differences were also discriminated either positively or
406 negatively only by their taste and/or texture. As the fruits were produced in three locations
407 and each cultivar was only grown in one place, it is not actually possible to separate the
408 influence of the growing location from the cultivar effect.
409 Three to four clusters of consumers were identified in each country, the clusters being
410 segmented first by taste then by texture attributes. The same trend was already found in a
411 previous preference mapping experiment in France (Lê and Ledauphin 2006; Lengard and
412 Kermit 2006).
413 The MFA allowed the comparison of panel assessment in spite of different glossary and
414 scales used in each country. The analysis revealed that consumers from different countries,
415 even with different cultures and food practices, had similar segmentation of preferences

when projected onto a common reference plan constructed with all the sensory descriptors. The HMFA allowed analysing relatedness between sensory profiles and consumer scores. In France, appearance descriptors were scored and the consumers and trained panels average scores were quite close. This indicates that it is important to introduce appearance descriptors in sensory profiles in order to get closer to consumer appreciation. This is in agreement with previous observations on the importance of fruit size (Bruckner and others 2007), colour (Francis 1995), as well as other information about the origin and growth conditions (if available) in consumer preferences (Johansson and others 1999).

Conclusion

In agreement with previous analyses, this study identified sweet and acid tastes, tomato flavour intensity and firmness as the most important traits for improving tomato fruit quality. It showed that consumers from different European countries, even with different cultures and food practices, have similar preferences when projected onto a common plan of sensory descriptors. Moreover the results clearly showed that diversification of taste and texture is required to satisfy all consumers' expectations as some consumers prefer firm tomatoes, while other prefer melting ones and that they are more or less demanding in terms of sweetness and flavour intensity.

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521

Figure captions

Fig. 1

First plan of the Principal Component Analysis based on sensory profiles obtained in France. Circle of correlations of descriptors

Fig. 2

Contour plot of the external preference map of the French consumers. The consumer scores were projected on the PCA constructed on the sensory descriptors (figure 1). The isolines correspond to the percentage of consumers who gave a score higher than average. Small dots correspond to consumers.

Fig. 3

Contour plot of the external preference map of the Dutch consumers. The consumer scores were projected on the PCA constructed on the sensory descriptors. The isolines correspond to the percentage of consumers who gave a score higher than average.

Fig. 4

Projection of the sensory descriptors common to the three countries on the first plan of a Multiple Factorial Analysis using three groups of sensory descriptors as active groups.

Fig. 5

Projection of all the sensory descriptors used in each country on the first plan of the Multiple Factorial Analysis based on 3 active groups (the three groups of descriptors)

Fig. 6

548 Contour plot of the external preference map of consumers on the Multiple Factorial Analysis
549 first plan based on the sensory profiles from the three countries (descriptors plotted on figure
550 5). A French consumers; B Italian consumers; C Dutch consumers
551
552 **Fig. 7**
553 First plan of the Hierarchical Multiple Factorial Analysis using as active variables the
554 coordinates extracted from two Multiple Factorial Analyses, one on the three groups of
555 sensory descriptors, the other on the three groups of consumer scores used in each country.
556
557 **Fig. 8**
558 Projection of the group average on the Hierarchical Multiple Factorial Analysis described
559 figure 7 for each cultivar

Tables

Table 1

Cultivars tested in each country, fruit type, average fruit weight (in grams), firmness (assessed in France) and growth place (NL: fruits provided by Nunhems, grown in the Netherlands, F-S: fruits provided by Rougeline, grown in Southern France; F-W: fruits provided by Saveol, grown in Western France)

Cultivar	Type	Fruit weight	Firmness°	Growth Place	Tested in France	Tested in Italy	Tested in Netherlands
Alison	Round	111	70	F-S	x	x	x
Bonaparte	Round	103	74	F-W	x	x	x
BS1504	Round	80	na	NL		x	x
Cheers	Truss	134	*59*	F-S	x	x	x
Climberley	Truss	144	*66*	F-S	x	x	x
Cotabel	Ancient	173	55	F-W	x	x	
Exquise	Round	167	66	NL	x	x	x
Fergie	Round	179	72	NL	x	x	x
Globo	Round	81	65	NL	x	x	x
Hipop	Ribbed	216	65	F-S	x	x	x
Marbonne	Ancient	186	47	F-S	x	x	x
Maribel	Round	106	68	NL	x	x	x
Marmandino	Green shoulder	120	na	NL			x
Nun3120	Round	80	69	NL	x	x	x
Picolino	Cocktail	26	52	F-S	x		
Plaisance	Truss	109	66	F-W	x	x	x
Red Delight	Cocktail	47	54	F-W	x	x	x
Savantas	Long	92	63	F-W	x	x	
Thesis	Round	130	na	NL			x

° Durofel index

572 **Table 2**
573 Descriptors used by sensory panels in each country
574

Descriptor	Dutch descriptors	French descriptors	Italian descriptors
Flavoour and basic tastes			
Overall flavour intensity*	t_intensity	t_Aromint	Overal _flavour
Sweet taste*	t_sweet	t_Sweet	Sweet
Acid taste*	t_sour	t_Acid	Acid
Salty taste*	t_salty	t_Salty	Salty
Tomato flavour	t_tomato		Tomatofl
Green flavour	t_green		Green
Earthy flavour	t_earthy		
Spicy flavour	t_spicy		
Sharp flavour	t_sharp		
Astringent mouthfeel	t_astringent		
Watermelon flavour			Watermelon
Fruity flavour			Fruity
Herbaceous flavour			Herbaceousfl
Texture			
Juicy texture*	x_moist	x_Juicy	Juiciness
Mealy texture*	x_mealy	x_Mealy	Mealiness
Firm texture*	x_firm	x_Firm	Firmness
Skin thickness*	x_toughskin	x_Skin	Skinthick
Crunchy texture		x_Crunchy	
Melting texture		x_Melting	
Odour			
Odour intensity	od_intens	od_Intens	
Tomato odour	od_tomato		
Spicy odour	od_spicy		
Sweety odour	od_sweety		
Smokey odour	od_smokey		
Other odour	od_other		
Appearance			
Ribbed appearance		a_Rib	
Firm appearance		a_Firm	
Tomato colour intensity		a_Colext	
Tomato size		a_Size	
Seed number			Seeds
Pulp thickness			Pulpthick
Watery aspect			Watery
Aftertaste			
Bitter aftertaste	at_bitter		at_Bitter
Sweet aftertaste	at_sweet		
Acid aftertaste	at_sour		
Salty aftertaste	at_salty		
Fresh aftertaste	at_fresh		
Chemical aftertaste	at_chemical		
Rough aftertaste	at_rough		

575 * Descriptors common to the three countries are indicated with a star

Table 3

Characteristics of products described by French panel

Average score for each cultivar and descriptor. The scores followed by + or - indicate the values significantly higher or lower than the average (P<0.05). The *decat* function ranks the descriptors and cultivars according to their overall proximity

	a_ Size	a_ Rib	x_ Mealy	x_ Melting	a_ Firm	x_ Juicy	x_ Firm	x_ Crunchy	t_ Salty	od_ Intens	t_ Acid	x_ Skin	a_ Colext	t_ Aromint	t_ Sweet
Cotabel	6.58 +	7.92 +	7.08 +	7.33 +	4.58 -	4.00 -	1.83 -	2.33 -	3.33	6.17	3.5	4.33 -	6.17 -	5.25	2.75
Marbonne	6.50 +	5.75 +	1.83 -	6.58 +	5.08 -	7.50 +	3.17 -	3.75 -	3.08	6.75	2.92 -	5.17	5.67 -	5.25	2.83
Hipop	7.33 +	2.17	3.92	5.08	6.75	6.17	4.83	5.00	2.83	6.17	3.75	4.42 -	6.33 -	5.08	2.50
Climberley	6.17 +	1.25 -	3.67	4.58	6.92	6.42	5.42	5.08	2.58	5.92	3.08	5.67	6.33 -	4.58 -	2.50
Plaisance	4.92	1.50	3.92	4.42	7.42 +	5.08	4.67	5.00	2.50	5.42 -	3.5	5.42	7.75 +	4.83	2.67
Cheers	5.42	1.25 -	2.58 -	5.92 +	5.83	7.17 +	3.83	3.33 -	3.42	6.67	3.00 -	4.58 -	6.92	4.92	2.92
Alison	4.75	0.92 -	3.75	3.33 -	7.42 +	5.33	5.92 +	6.08 +	2.67	6.17	3.00 -	5.83	5.25 -	4.92	3.67
Fergie	7.08 +	2.25	4.83 +	5.50	6.92	5.08	4.33	4.83	3.25	6.42	4.58	6.08	7.67 +	5.42	2.33 -
Nun3120	3.75 -	0.67 -	4.58 +	3.83 -	7.75 +	5.08	5.75 +	5.25	2.67	5.75	3.92	6.08	7.42	4.92	3.00
Savantas	3.92 -	0.58 -	4.25	6.58 +	4.75 -	5.83	3.00 -	3.08 -	3.08	6.42	3.33	5.17	6.92	5.92	4.42 +
Bonaparte	4.50 -	1.67	2.67 -	2.75 -	7.83 +	4.83 -	6.67 +	6.42 +	2.17	6.33	4.00	5.08	6.83	4.92	3.75
Maribel	4.67	1.25 -	4.83 +	3.42 -	7.25 +	4.92 -	5.17	5.58	3.17	6.83	4.92 +	7.00 +	6.75	5.58	2.58
Exquise	6.33 +	1.58	3.08	4.33	6.25	6.33	4.67	4.83	2.75	7.08	5.08 +	6.08	7.50 +	6.50 +	3.08
Globo	3.92 -	1.42 -	3.92	3.42 -	7.33 +	4.83 -	6.08 +	6.83 +	3.50	6.83	3.75	7.08 +	7.50 +	5.83	4.58 +
Red Delight	2.75 -	0.58 -	2.58 -	6.75 +	4.58 -	6.75 +	3.17 -	3.75 -	4.00 +	6.75	4.33	5.92	7.50 +	7.17 +	5.42 +
Picolino	1.92 -	0.75 -	1.08 -	4.25	4.67 -	6.58 +	5.08	5.67	4.17 +	7.08	5.08 +	6.17	8.58 +	7.08 +	5.92 +

584 **Table 4**
585 Mean preference scores per cultivar in France and the Netherlands
586 The scores followed by + or - indicate the values significantly higher or lower than the
587 average. For the cultivars significantly discriminating each segment identified by the
588 hierarchical cluster analysis, the difference from the average score in each segment is
589 indicated, with the number of consumers per segment (N).
590

	France (mean =5.59)					Netherlands (mean = 5.87)				
	Mean (sd)	segment 1 N = 72	segment 2 N = 98	segment 3 N = 49	segment 4 N = 85	Mean (sd)	segment 1 N=60	segment 2 N=136	segment 3 N=80	segment 4 N=47
Picolino	7.19 (1.79) +	0.62	1.27	2.37	2.31	na				
Red Delight	6.59 (1.80) +	0.16		2.08		7.05 (1.76) +	2.26	0.42	1.57	
Savantas	6.23 (1.94) +	0.23				na				
Cheers	5.71 (1.89)	-0.30		0.80		6.65 (1.91) +	1.34	0.34	1.43	0.20
Exquise	5.69 (1.92)		0.82	-0.79	-0.44	6.24 (2.03) +	-0.24			1.26
Plaisance	5.64 (1.79)					5.72 (2.00)	-1.29	0.21	0.53	-0.87
Marbonne	5.49 (2.29)	0.55	-1.79		1.37	5.01 (2.45) -	0.39	-0.11	-3.23	
Alison	5.49 (1.92)					5.59 (2.11) -			0.12	
Globo	5.44 (2.02)		0.24			6.27 (2.08) +	1.42	0.06		-0.44
Bonaparte	5.41 (1.93)					5.84 (2.10)				-0.72
Hipop	5.41 (1.97)	0.45			-0.53	5.57 (2.19) -				
Fergie	5.35 (2.09) -		0.33	-1.10		5.98 (2.14)			-0.41	1.54
Maribel	5.16 (2.00) -	-0.08		0.08	-1.21	5.52 (2.11) -	-1.23	0.14		-0.85
Climberley	5.16 (2.00) -		-0.1		-0.87	6.01 (2.11)			0.78	-1.76
Nun3120	4.91 (2.06) -		-0.41		-1.13	5.13 (2.29) -	-1.99	-0.44		0.52
Cotabel	4.63 (2.35) -	-0.28	-1.67	-2.69	0.27	na				
BS1504	na					6.11 (1.98) +	-0.61		0.97	
Thesis	na					5.85 (2.15)	0.49			
Marmandino	na					5.41 (2.30) -			-1.37	0.64

591 na : non available